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Abstract

In the framework of the research project “B³RetroTool”, a typology of existing dwellings, built before 1945, has been made, based on a literature review of main steps of the urban and building development of Brussels area. This old part of the Brussels dwellings stock has been chosen because it represents 60% of the dwelling stock but moreover, it gives to Brussels its identity, its architectural and its historical legacy. This contribution presents the methodology to identify typology, to structure a representative database of existing dwellings stock (with spatial distribution in Brussels area) and to define criteria to assess retrofitting strategies for each dwelling type in order to enhance heritage value and to combine it with relevant energy and environmental performances. The originality of this research is to consider energy, environmental and heritage aspects in a non-compartmentalized and complementary way, in order to help designers to reach their objective of a great...

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Assessing Sustainable Retrofit of the old Dwellings Stock in Brussels Capital Region

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ABSTRACT

In the framework of the research project "B³RetroTool", a typology of existing dwellings, built before 1945, has been made, based on a literature review of main steps of the urban and building development of Brussels area. This old part of the Brussels dwellings stock has been chosen because it represents 60% of the dwelling stock but moreover, it gives to Brussels its identity, its architectural and its historical legacy.

This contribution presents the methodology to identify typology, to structure a representative database of existing dwellings stock (with spatial distribution in Brussels area) and to define criteria to assess retrofitting strategies for each dwelling type in order to enhance heritage value and to combine it with relevant energy and environmental performances. The originality of this research is to consider energy, environmental and heritage aspects in a non-compartmentalized and complementary way, in order to help designers to reach their objective of a greater sustainability.

INTRODUCTION

The dwellings stock built before 1940 in Brussels has a great heritage value for Brussels Capitale. It also represents 60% of built areas and is responsible for 62% of the region's energy consumption. This fact has prompted Brussels to invest in strong support for reducing energy consumption in buildings through systems of subsidies. These include subsidies for insulation, replacement of windows, boilers ... So as to target the strategic policy actions in terms of reduction; the Brussels Capital Region has also invested in targeted studies on the state of the existing building stock and opportunities for improvement. All of these studies, mainly based on statistical studies have rarely considered both the heritage and historic value of the buildings and the improvement potential related to buildings components and design principles.

The research's objective is to achieve important improvements in the energy performance of existing Brussels dwellings stock while preserving heritage value and reducing environmental impact.

The research focuses only on the dwelling stock built before 1940 for three main reasons. First, this is the largest share of the Brussels dwellings stock. Secondly the differents types of dwelling could easely be identified.Thirdly, this dwellings stock requires urgent improvements in terms of energy performance and inhabitancy. It should also be noted that dwelling demand is very strong in Brussels. So the retrofit of this dwelling stock could meet this demand by densifying some dwelling types.

This contribution presents identification of dwelling typology built before 1940, proposition of retrofitting scenarios and definition of energy, environmental and heritage value criteria in order to

enhance heritage value of the Brussels dwellings stock and to combine it with relevant energy and environmental performances but also suitable materials and systems. It describes in details the methodology used for identification, repartition and spatial distribution of dwelling typology. Retrofitting scenarios and assessment criteria are subsequently presented.

This research is still ongoing and the results of scenarios assessment are not yet known. The overall results: dwelling typology, its repartion and spatial distribution as well as improvement scenarios and their assessment through case studies will be incorporated into a pre-assessment tool to retrofit the dwellings in an integrated multi-criteria and multi-scale approach.

HISTORICAL RESEARCH: URBAN DEVELOPMENT OF BRUSSELS, FROM THE 10TH TO 20TH CENTURY

The first step of the research was to study the historical processes [1, 2, 3, 12] that have influenced the development of the city of Brussels and the Brussels-Capital Region in order to understand the urban characteristics and specificities but also to know the origin of the development of certain types of city blocks and dwellings. Brussels-Capital Region, as it is today, was formed mainly during the last two centuries. But some key elements are older. They are, as example, the topographic or hydrographic elements that were at the origin of the spatial and social differentiation between high side (east and more aristocratic) and low side (western, most popular and industrial) of the city. This spatial and social differentiation is still present today, although less pronounced than originally. It is also the work of fortifications that gave the city center of Brussels, a specific and still visible form. It is also major infrastructure projects such as the creation of the boulevards on the second enclosure, the creation of Willebroeck and Brussels-Charleroi canals, the creation of large avenues, the creation of the North-South Train Junction... All those elements must still be reconsidered in strategies for urban renewal of the region through different scales: neighbourhoods, city blocks and buildings.

This historical research focuses mainly on morphology, demography, urban planning, architecture and types of dwelling.

DEFINITION OF DWELLING TYPOLOGY

The study of the dwelling typology before 1945 has been established from the late 17th century for two main reasons. First, dwellings built before 1700 are mainly wooden buildings. In 1695, those wooden buildings were almost destroyed (as the entire city) by the French bombing. The Brussels rebuilding was made with bricks and stones, on the track of the old wooden dwellings. Secondly building permits and the various regulations standardizing construction spread in the 18th century.

Dwelling types were defined according to the historical research of Brussels urban development but also to the changes in lifestyle of Brussels citizen as well as changes in construction methods and materials used. Three main periods of urban development have been identified.

From 1700 to 1890: urban development of Brussels. Period characterized by the first great works of urbanization and development of the future Belgian capital city (1830).

From 1890 to 1914: transition period. Period characterized by hesitation between the nostalgia for the past and the desire for modernity and a new architectural trend, the "Art Nouveau" launched by Victor Horta, with the construction of Hotel Tassel in 1893.

From 1920 to 1945: modern period. Period characterized by a strong demand of housing but also new ways of thinking architecture and urban development.

Regarding the types of dwelling, the research distinguished two key periods:

From 1700 to 1914. Period characterized by a predominance of individual housing (modest, bourgeois and aristocratic), whose spatial organization will be based on the spatial organization of the "maison bourgeoise";

From 1920 to 1940. Period characterized by the emergence of new types of dwellings, mainly worker house in the garden cities and apartment building but also new constructive processes and new materials, especially concrete.

Based on archival and/or historical documents, each type of dwelling has been studied according to the methodology including a general description of the type (description of dwelling situation, spatial organization, internal circulation and stair case, building systems and materials, roof, façades and building materials), a description of the main characteristics (relation with public space, size of the plot, size of the building, volume, number of floors, presence of annexe, height and width of the main façade…) and description of type variations if they exist.

Dwelling typology from 1700 to 1914 [4, 5, 11, 14]

The single family row house is the most common form of dwelling in Brussels until 1914. For this period, there are three main types of dwelling: the "maison bourgeoise", the modest or worker house and the "hôtel de maître". These types are the evolution of the Brussels wooden row house and are thus characterized by the same spatial organization, construction principles and materials that can be presented through the "maison bourgeoise":

Spatial organization. It reflects the lifestyle of the bourgeoisie in the 19th century and it is organized in three modes: reception, family spaces and services or domestic spaces. Internal spaces are divided into two parts: a main part including the reception and living spaces and a secondary part, narrower, including services, stairs and corridors. The plan is organized with a succession of two or three rooms with a depth of 4 to 4.5 meters. Reception and living spaces have high ceilings, large width and are largely lit.

Construction system, principles and materials. The construction system is mainly governed by the rules of protection against urban fire. It is based on the constructive system of the Brussels wooden row house. Party walls are made of brick locally sourced and are not structural. The wooden floors are perpendicular to the street facades and partition walls. The wooden beams are spaced between 35 and 40 cm. The thickness of the bearing brick walls is also codified by the regulations of buildings to ensure stability. It varies between 28 cm and 48 cm depending on the type and height of walls. Recovery of floors charges and load-bearing walls is ensured by a combination of discharge vaults and metal lintels scattered throughout the façade and load-bearing walls. Only the structure of the roof is based on party walls, wooden beams ranging from wall to wall. The floors of the ground floor are partly made of hard materials. They are tiled or covered with marble. Floors of the upper levels are in wood. The ground cellars are usually performed in clay.
The two façades are narrow (6 m) and high (12 to 18m) but there is however a big difference in composition between the two façades. Back cover: brick facade, sober and coated. Only a few metal lintels and sills are apparent. Main façade composition depends on different styles: neoclassical, eclectic,... Materials used are brick, natural stone and oak for window frames. The level of the street façade decoration shows the social level of inhabitants.

Dwelling type variations. The type "maison bourgeoise" could be divided into three variations according the construction date: "maison bourgeoise" built before 1800, "neoclassical maison bourgeoise" and "maison bourgeoise bel étage". Those three variations have the same spatial organization and same internal plan but show variations at the level of groundfloor and stairs installation.

The same construction systems and materials are found in the modest house and in the "hotel de maître". Only the location, the size of the plot, the width of the main façade, the surface area, number of floors, the appearance of the street façade and interior finishes are different. Modest or worker row houses were mostly located in the popular and industrial districts. Maisons bourgeoises were located in residential districts of the pentagon, mainly in the top of the city. Hôtels de maître built for the upper bourgeoisie and aristocracy, after 1830, were located along large avenues and in some districts extensions. In addition to these three types, there are also houses with shop and apartment houses that show a lot of similarities with the "maison bourgeoise". Those types of dwelling were located on the corner plots and near train stations and infrastructure.

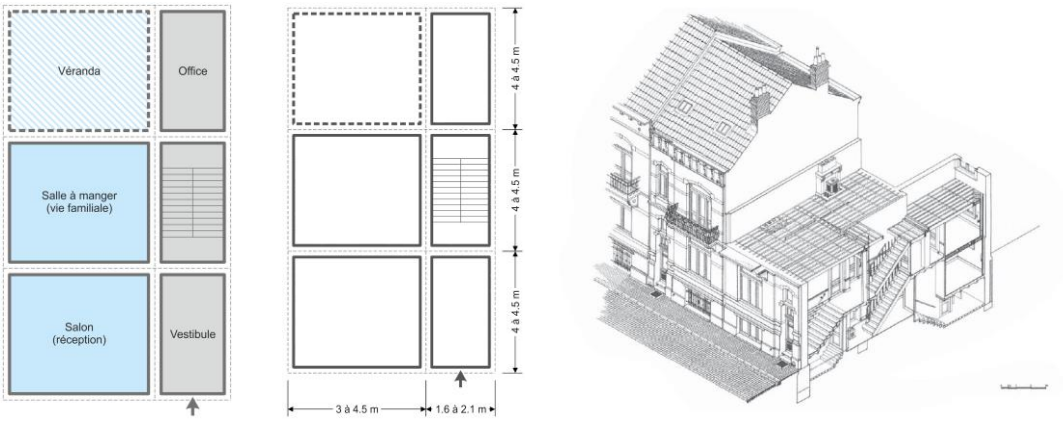

Figure 1 Left: Spatial organization - Center: main dimensions - Right: construction principles of the "maison bourgeoise"

Dwelling typology from 1920 to 1940 [6,7,8, 14] **.**

The beginning of World War I, in 1914, traditionally marks the end of a period both in Western Europe in Brussels. Mentalities as well techniques evolve significantly: the car is spreading, domesticity disappears, the role and place of women change. Changes also appear in the ways of life of the bourgeoisie and the working population. These changes have an impact on the spatial organization of dwellings, on the urban development of Brussels and on the types and styles of dwellings whether individual row house remains predominant. Garden cities are built for the workers at the extremities of the city. By 1930, after the financial crisis of 1929, apartment buildings for middle class - back in town - are growing in Brussels. For this period, we can distinguish three types of dwelling: evolution of the "maison bourgeoise", worker row house in garden-city and apartment building (social and standard). If the evolution of the "maison bourgeoise" still presents many spatial similarities with the "maison bourgeoise" built before 1914, the two other types show a new spatial organization [figure 2]. All three types also were built with new construction systems, principles and new materials, especially concrete.

Figure 2 Left: Plan of garden-city row house (1922) – Right: plan of standard apartement building (1930)

Case studies of dwelling types

For each type of dwelling, a case study sufficiently representative has been searched. With this objective, various Brussels databases and information sources [15] have been consulted and various architects working with old buildings and dwellings have also been contacted. Each case study will be analysed based on original plans, sections and detailed quantity survey.

Figure 3 Pictures of “neoclassical maison bourgeoise”, “maison bourgeoise bel étage”, “hotel de maître”, apartement house, evolution of maison bourgeoise 1, evolution of maison bourgeoise 2, standart apartement building and social apartement building.

Building stock analysis – Dwelling type repartition

Based on the description of each dwelling type, a simplified characterization has been proposed to fit the data given in the Brussels cadastral matrix (©Administration Generale de la documentation patrimoniale) and to associate each lot to one type. As we can see in the figure 4, the characterization is limited to three factors: date of construction, floor area, number of dwellings per building. There is a total of 159825 buildings and 498819 dwellings registered in the Brussels cadastral matrix.

Type	TYPES BATIMENT B³-RetroTool	avant 1850	1850-1874	1875-1899	1900-1918	1919-1930	1931-1945	Surf utile / Bat	Nb log / Bat	Surf/Log
0	Non applicable								0 ou 999	< 8
1a	Maison bourgeoise d'avant 1850							120-350		
1b	Maison bourgeoise type leopoldien (néoclassique)							120-350		
2a	Maison bourgeoise avec bel étage (1 logement)							120-350	= 1	
2b	Maison bourgeoise avec bel étage (> 1 logement)							120-350	> 1	
3a	Hotel de maître ou hôtel particulier							351-1000	<= 4	
3b	Maison de rapport							351-1000	> 4	
4a	Maison modeste d'avant 1919							25-119		
4b	Maison modeste après 1918 (dont cité-jardin)							25-119		
5a	Maison bourgeoise - Evolution (1 logement)							120-350	= 1	
5b	Maison bourgeoise - Evolution (> 1 logement)							120-350	> 1	
6	Immeuble à appartement							>350		
7	Après 1945									

Figure 4 Characterization of dwellings types

The figure 5 confirms that more than 60% of the buildings were built before 1945. This analysis shows that "maison bourgoise” (type 2 in the figure) outnumbers all other types and that many post-war buildings are apartments.

Then, with ArcGIS software, the resulting database can be used to analyse spatial distribution of each type. The left map [figure 6] shows that type “maison bourgeoise” was mainly built close beyond the first encloser. The right map [figure 6] shows that after 1918 the type “evolution of maison bourgeoise” (type 5) was built further out the centre, beyond the second encloser.

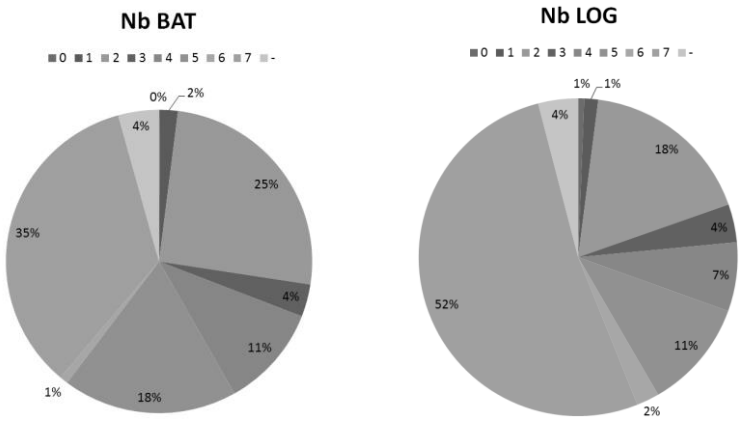

Figure 5 Repartition of dwellings types by building (left) and by dwelling (right)

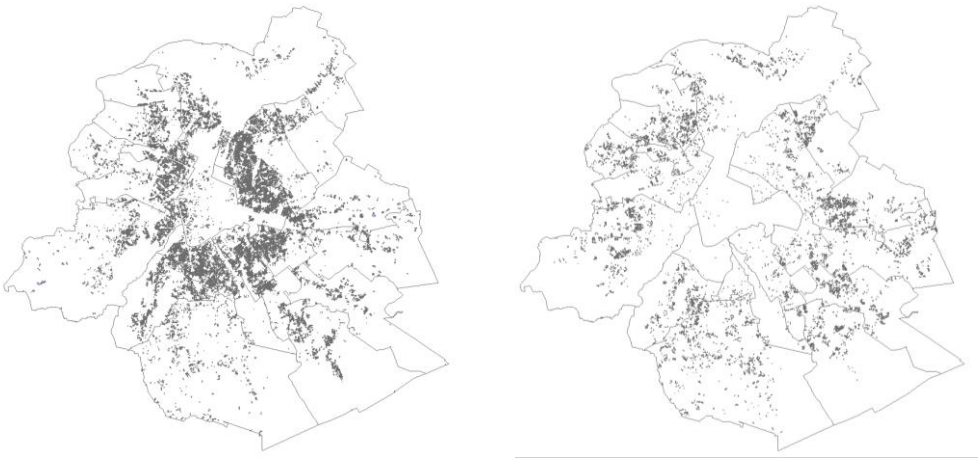

Figure 6 Spatial distribution of dwellings types: left: “maison bourgeoise” built before 1914 and right: “evolution of maison bourgeoise” built between 1920 and 1930

ASSESSMENT OF POTENTIAL IMPROVEMENTS OF DWELLINGS STOCK

Based on the description of each dwelling type, various scenarios of retrofitting were proposed. They focused mainly on improving the energy performance of each dwelling type but also on creating opportunities for dwelling densification, function diversity and inhabitancy improvement. Scenarios proposed for each dwelling type will then be applied to the specific case study and assessed according to three criterias (heritage value, energy and environmental impact) and compared with the initial situation.

Climatic data of Brussels Capitale Region

The reference Belgian external climate is a relatively cold, humid and rainy temperate climate. The data presented below, were measured by the Belgian Weather Royal Institute in Uccle (Longitude: 4.36°E, Latitude: 50.80°N; Altitude 100 m): average temperature (9.9°C), average relative humidity of the air (80%), average wind speed and orientation (3.6 m/s, south-west), average global solar radiation (108 W/m² with min:0 - max 889) and average precipitation (930 mm per year).

Assessment criteria

Each assessment criteria - energy, heritage value and environmental impact - contains a series of indicators presented in the table on the next page.

Table 1. Assessment criteria

Energy	Heritage value	Environmental Impact
Transmission coefficient [U] of the walls and frame	Building quality	LCA of building materials (GWP, AP, POCP)
Efficiency of the technical systems	Coherence quality	Amout and type of waste produced
Overall performance of the dwelling: - Average U - Level E	Preservation quality	LCA of technical systems (GWP, AP, POCP)
Total grey energy (NRE, RE)	Resilience quality	

Potential improvements of dwellings stock – retrofitting scenarios [9, 14, 15]

Various scenarios were proposed with the objective to improve significantly the energy performance of the dwellings. Those scenarios focused first on the envelope and then on the technical services. The envelope retrofitting scenarios were defined based on a trend analysis performed on the renovation of housing awarded at Exemplary Buildings initiated by Brussels Environment. They are proposed by phases, knowing that today, only few Brussels owners can finance all of the retrofitting works in one phase. The retrofitting steps are proposed in a hierarchical manner, taking into account the state of the dwelling, the influence on the energy performance and the extent of work required. As an example, the envelope retrofitting scenarios for the "maison bourgeoise" are the following:

1. *Roof insulation:* the insulation could be done from inside or outside. Insulation from inside preserves the structure and the covering. Insulation from outside requires a new covering and sometimes a new structure. Insulation from outside also requires a special attention to specific elements and ornaments and could be linked with integration of renewable energy system
2. *Roof insulation + Floor slab insulation*
   In case of "maison bourgeoise bel étage" with a raised ground floor and cellars naturally lit, the floor slab could be insulated from inside. In case of "neoclassical maison bourgeoise" with a ground floor at street level and cellars without natural light, the floor between ground floor and cellars could be insulated (cellars side).
3. *Roof insulation + Floor slab insulation + Frame replacement (back cover façade)*
   In many dwelling, frames are still equipped with single glazing. Those should be replaced by double or triple glazing frames taking into account the possible installation of solar protection (orientation) and increase of the airtightness.
4. *Roof insulation + Floor slab insulation + Frame replacement (back cover façade) + back cover façade insulation*
   Back cover façade could easely be insulated from outside. The most common technique is the coating on EPS insulation but wood-based materials will also be assessed.
5. *Roof insulation + Floor slab insulation + Frame replacement (back cover façade) + back cover façade insulation + Glazing and/or frame replacement (main façade)*
   The main façade being highly ornamented and the frame strong, the replacement of the frame and/or glazing therefore requires a detailed study. Several solutions can be considered: preservation of existing chassis and replacing single glazing by double glazing or replacement of all
6. *Roof insulation + Floor slab insulation + Frame replacement (back cover façade) + Back cover façade insulation + Glazing and/or frame replacement (main façade) + Main façade insulation*
   The main façade being highly ornamented, insulation from outside is really not possible. Insulation by inside means to pay attention to thermal bridges between façades and wooden beams and requires a detailed study [10].

The technical services retrofitting scenarios are proposed taking into account the existing technical services and the possible densification of the dwelling. The scenarios propose improvement strategies for

existing techniques but also for integration of ventilation systems, renewable energy systems (solar thermal and PV), rainwater infiltration systems and acoustic insulation (in case of dwelling densification). They presented, for each dwelling type, solutions for ducts implantation.

The densification retrofitting scenarios analyse the possible way to increase the number of dwelling, especially into the "maison bourgeoise" characterized by a very large surface area available (up to 400 m²). Some scenarios propose a diversity of functions by integrating professional spaces into the dwelling.

CONCLUSION

The paper presents the methodology used to analyse and caracterise the brussels existing dwellings stock. The data will be used to develop a tool to help improving global performance of this urban area. A definition of dwelling typology was detailed and each building from cadastrial database was associated with one type. Using ArcGIS tool, a map of each type can be drawn. For each type, refurbishment scenarios were proposed, as well as three set of criteria to assess energetic, environmental and heritage value in parallel. Developping tool should thus allow assessing simultaneously these three aspects and their interactions. This methodology can be applied in other contexts to provide any user with data at different scales, from the building to the entire city, helping to take sustainable decisions.

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REFERENCES

[1] Declève B., Ananian P., M.Anaya, A.Lescieux, Densités Bruxelloises et formes d'habiter, AATL, Région de Bruxelles-Capitale, Bruxelles, 2009
[2] P.Charruadas, Ch.Dessouroux, Etude historique de la Région Bruxelloise, des grandes formes urbanistiques et de la législation sur le bâti, ULB – IGEAT, AATL, Bruxelles, 2003
[3] V.G. Martiny, Bruxelles, l'Architecture des origines à 1900, Nouvelles Editions VOKAER, SA, Bruxelles, 1980
[4] V. Heymans, Les dimensions de l'ordinaire: la maison particulière entre mitoyens à Bruxelles, L'Harmatan, Paris, 1998
[5] V. G. MARTINY, La maison bourgeoise unifamiliale à façade étroite, du 16ème siècle à l'aube du 20ème à Bruxelles. In: BAETENS, R. & BLONDÉ, B. (eds.) Nouvelles Approches Concernant La Culture De L'Habitat / New Approaches to Living Patterns: Colloque International, Université d'Anvers, Brepols Publishers, 1991
[6] M.Smets, L'Avènement de la cité-jardin en Belgique, Histoire de l'habitat social en Belgique de 1830 à 1930, Edition Pierre Mardaga, Bruxelles, 1977
[7] P. Van Dijk, Immeubles à appartements de l'entre-deux-guerres, région Bruxelles-Capitale, Collection Bruxelles, Ville d'Art et d'Histoire, Bruxelles
[8] A. Braumann, L'Immeuble et la parcelle, les immeubles à appartements comme éléments constitutifs du tissu urbain. Le cas de Bruxelles. 1870 – 1980, AAM, Bruxelles, 1982
[9] S.Trachte, A. De Herde, IEA task 37 publication, "Advanced and sustainable housing renovation – A guide for Designers and planners", 2010
[10] A.Evrard, A.Branders, A.De Herde « Guide pour l'isolation par l'intérieur des murs existants en brique pleine », ISOLIN, SPW-DGO4, 2011
[11] G. Ledent, Potentiels Relationnels - L'aptitude des dispositifs physiques de l'habitat à soutenir la sociabilité. Bruxelles, le cas des immeubles élevés et isolés de logement, PhD Thesis, 2014, UCL
[12] JP de Visscher, Indivision PhD Thesis, 2013, UCL
[13] JP Gerkens « Les copropriétés acteurs de la performance énergétique en Région de Bruxelles-Capitale. Détermination des obstacles principaux et des solutions. », Master thesis, IGEAT, 2010
[14] J.Bigorgne, F.L'Hénaff «Amélioration des performances énergétiques du bâti ancien de la Région Bruxelles-Capitale», APUR publication, 2013
[15] Exemplary Buiding « BATEX » database, Brussels Environment - http://www.ibgebim.be